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A Computational Analysis of Psychopathy Based on a Network-Oriented Modeling Approach

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Abstract. In this paper psychopathy is analysed computationally by creating a temporal-causal network model. The network model was designed using knowledge from Cognitive and Social Neuroscience and simulates the internal neural circuit for moral decision making. Among others, empathy and fear are considered to affect the decision making. This model provides a basis for a virtual agent for simulation-based training or a support application for medical purposes.

Keywords: Psychopathy · Network-Oriented Modeling
Computational analysis

1 Introduction

Modeling is the key to simplifying complex real-world processes in science which allows one to study these processes in tangible portions. The field of Artificial Intelligence has addressed modeling of cognitive processes behind intelligence since the beginning, and the influence of emotion in cognitive models is growing. These human-like models are necessary for engineering virtual agents and emotions are now a broader accepted influence of the decision making processes in the brain; e.g., (Loewenstein and Lerner 2003, p. 619). The mental disorder psychopathy is the target domain of this computational analysis. This disorder is characterized by brain deviations and differences in behavior compared to healthy individuals. Research has been done on how this can be mapped out and simulated. As there are not many computational models yet for the specific domain of Psychopathy, the research presented in this paper forms a possible basis for more future research in this area.

A temporal-causal network model (Treur 2016) for psychopathy was created and tested in a situation that draws out psychopathic behavior in people with this disorder. The setting is a room in the public area, for example, a waiting room at a train station. One person walks out of the room and accidentally leaves behind his or her wallet. Another person might pick up the wallet and give it back, or might choose to steal it, despite that there are other people present. Our model will computationally address how this (mostly unconscious) decision making process works and how it differs between healthy individuals and persons with psychopathy. The main aspects found

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that play an important role in this are empathy and fear, which would both inhibit one's propensity to grab the wallet. In contrast, a motivator to grab the wallet would be gain, which represents how taking the wallet would improve the situation of this person.

This computational analysis is mainly targeted at the Cognitive Agent Modeling field of Artificial Intelligence and integrating the fields Neuroscience, Criminology and Artificial Intelligence in a manner that benefits all. It provides a basis for a virtual agent that addresses psychopathy. This virtual agent model could be a great advantage in empirical research or in an educational setting. A model closest to a computational model for psychopathy is a more general agent-based model for criminal behaviour (Bosse *et al*. 2009). In the model introduced in the current paper the relevant cognitive and neural processes are addressed in more detail.

In Sect. 2, the (neurological) background of this research and related literature are discussed. Section 3 covers the modeling segment. The computational network model, which is based on Sect. 2, is introduced. Section 4 addresses the experimental work and some of the results that were achieved. Finally, Sect. 5 is a discussion.

2 Background on Psychopathy

Psychopathy falls under Antisocial Personality Disorder, or ASPD. Whereas Conduct Disorder is the childhood version of ASPD and psychopathy, adults either have ASPD or ASPD with psychopathy. ASPD is characterized by a lack of remorse or empathy for others, cruelty, poor behavioral controls, recurring difficulty with the law, promiscuity, inability to tolerate boredom, irresponsibility and the tendency to violate the boundaries of others (Vervaeke 2016). On top of these characteristics, people with ASPD and psychopathy also are often manipulative, highly intelligent, have a grandiose sense of self-worth, superficial charm and they are not good at detecting emotions, especially fear, in others as well as themselves. Psychopathy is considered to form the dark triad together with narcissism and Machiavellianism. Narcissists often also express psychopathic tendencies (Muris et al. 2017; Ronningstam 2010) but the research in this paper will focus on people with ASPD and psychopathy.

How do these phenotypical characteristics look in the brain? Neuroimaging studies found that the dorsal and ventral regions of the prefrontal cortex (PFC), the amygdala, hippocampus, angular gyrus and posterior cingulate are functionally or structurally deviating in persons with psychopathy. These overlap somewhat with the regions that are activated in moral judgement tasks, such as whether to steal a wallet or not (Raine and Yang 2006). These regions are the medial PFC, ventral PFC, amygdala, and the regions less impaired in psychopaths; the angular gyrus and posterior cingulate.

Rule-breaking behavior is partly caused by impairments in the structures dorsal and ventral PFC, amygdala, and angular gyrus, which serve moral cognition and emotion (Vervaeke 2016). Similar findings were described by Blair and James (2013). They found that several functions were compromised. These regions are the amygdala, ventromedial PFC (vmPFC), the connectivity from amygdala to vmPFC (especially when making moral judgements), and the uncinate fasciculus (a route of white matter in the brain that connects, among others, the amygdala with the frontal brain structures). They also found that amygdala responsiveness to emotional cues was reduced in psychopaths, which is associated with a lack of empathy (callousness) and a lack of guilt. No impairment in cognitive empathy was observed. Structurally, the amygdala volume is found to be reduced as well as the structural integrity of the vmPFC. Combined with the reduced functional connectivity from amygdala to vmPFC in individuals with psychopathic traits, this means in particular that the amygdala, vmPFC, and the upward connection from amygdala to vmPFC is impaired in psychopaths. These regions are associated with emotion and emotion processing (Salzman and Fusi 2010).

Empathy was defined by Keysers and Valeria Gazzola (2014) as “feeling what we would feel in another’s stead”. Using this definition, Keysers makes the point that there are many ways to measure empathy, and these all acknowledge different facets to empathy. A distinction between these facets could be between cognitive or emotional empathy, or between fantasizing, perspective taking, personal distress or empathic concern. Another common distinction is between actions, emotions and sensations. Keysers’ argues that a different dissociation, one between ability and propensity of empathy for different facets of empathy, could help neuroscience. Shirtcliff et al. (2009) has a definition of empathy that is very close to Keysers’. It is described as “the recognition and sharing of another’s emotional state”, which touches some more on emotions than Keysers did. Their focus is mainly on emotional empathy, but they also acknowledge cognitive empathy, which is closer to the Theory of Mind (Blair et al. 1996; Bosse et al. 2011). Theory of Mind is the ability to represent someone else’s mental sates such as thoughts, desires, hopes and feelings. This cognitive empathy or Theory of Mind is shown to be present in psychopaths, who perform even better in Theory of Mind than most highly able autistic adults (Blair and James 2013). From this it can be concluded that psychopaths do not, per definition, have a deficit in cognitive empathy. The ability of cognitive empathy is present (Blair et al. 1996). Experiments have also shown that psychopathic individuals can have the ability to empathize in situations that encourage empathy. However, individuals with psychopathy have a different propensity for this ability than healthy individuals do (Keysers and Valeria Gazzola 2014). Shirtcliff et al. (2009) found something similar, namely that empathy is not completely automatic. Some of the processes behind this ability to empathize depend on attention or motivation. It is likely that motivating situations encourage psychopaths to empathize with others, while other situations do not encourage them when helping is costly. Empathizing with someone can increase that person’s trust in you, giving you access to their resources. A psychopath would be more likely to empathize in such a scenario (Keysers and Valeria Gazzola 2014). From a neuroscientific perspective, psychopaths have shown reduced amygdala activation and fear, although this normalizes when attention is focused on emotion of the stimuli (Marsh et al. 2013; Keysers and Valeria Gazzola 2014). Lesions in amygdala, associated with psychopathy, reduce fear attribution unless this person’s gaze is directed to the eyes of the other person. This, combined with the dependency of empathy on attention and motivation, indicates some very powerful regulating circuit for empathy.

Similar to empathy, fear has several definitions. While it is sometimes described as “a feeling of great worry or anxiety caused by the knowledge of danger” (Kosson et al. 2016) in research about psychopaths it is defined with “anxiety as emotions to describe unpleasant state or tension”. Physiological arousal is associated with these emotions, including increased heart rate, respiration and sweating (Kosson et al. 2016). *Earlier,* psychopathy was associated with the absence of nervousness and reduced major affective reactions. Psychopaths were considered to be fearless of danger and punishment. They were thought to be capable of experiencing momentary discomfort or fear of an immediate danger, but not the kind of worrying about future consequences, which ultimately means no fear to be arrested when committing a crime (Kosson et al. 2016). More recently, youths with psychopathic traits reported that they experience less frequent and less intense fear than non-psychopathic youths did. This might be evidence for the disruptions in fear processing in psychopaths that psychopathy is known for (Kosson et al. 2016). The structural and functional impairments of the amygdala discussed above are also observed by Schultz et al. (2016). This structure is associated with fear and emotion processing which lead to the support of a low-fear model of psychopathy. Schultz argues for a distinction between two types of psychopaths who express fear in different ways. He found that primary psychopaths, characterized by constitutional fearlessness, show normal fear expression in a fear conditioning study. In the same study, Secondary psychopaths, characterized by problematic behavior motivated by other factors than fearlessness, expressed a pattern consistent with fear inhibition. He argues that the low fear that is associated with psychopaths might be specific to secondary psychopaths. While psychopathy can be split up in two types, the primary and secondary type, fear can be as well, Hoppenbrouwers et al. (2016) claim. Fear has been used generically, while differences between threat detection, responsivity and the conscious experience of fear are observed. This differentiation might be the cause of the dissension that can be observed in research into fear in psychopaths. Hoppenbrouwers and Bulten make a distinction between threat responsivity and detection versus the conscious experience of fear. Their findings suggest that psychopaths have behavioral and neurobiological deficiencies in threat detection and responsivity, but seem to be able to consciously experience fear as an emotion. Kosson et al. (2016) state that it appears that psychopaths are not generally under-responsive to aversive stimuli. They seem to have a conscious or unconscious coping style that protects them from the negative emotional effects of aversive stimuli when they are prepared for those stimuli. This might indicate that psychopaths also have some sort of fear regulation system that is more developed than in normal persons. This, in a sense more advanced coping style in threat detection, might form an explanation why psychopaths do not avoid the aversive situations that healthy individuals would avoid. It was also found that attention plays an important role in the relationship between psychopathy and the startle reactions of fear, although this relationship is complex (Newman and Baskin-Sommers 2011). Research shows that the deficits in fear and anxiety in psychopaths can be attributed to lack of attention, similar to the findings on empathy. When psychopaths are less focused on emotion, their brain systems for emotion are less activated (Kosson et al. 2016). Psychopaths seem to tune out threatening stimuli by their form of fear regulation.

3 Modeling Psychopathy

The adopted modelling approach is the Network-Oriented Modeling approach described in (Treur 2016). This is an approach that addresses the complexity of human and social processes and uses temporal-causal networks as a vehicle, in which causes and consequences are set out over time. Treur (2016) shows that any smooth dynamical system can be modeled by a temporal-causal network, especially from the Cognitive, Affective and Social domains. In a temporal-causal network model the states are assumed to have (activation) levels that vary over time. As not all causal relations are equally strong, some notion of *strength of a connection* is used. Furthermore, when more than one causal relation affects a state, some way to *aggregate multiple causal impacts* on a state is used. Moreover, a notion of *speed of change* of a state is used for timing of the processes. These three notions are covered by elements in the Network-Oriented Modelling approach based on temporal-causal networks, and form the defining part of a conceptual representation of a specific temporal-causal network model:

- **Strength of a connection $\boldsymbol{\omega}_{X,Y}$** Each connection from a state X to a state Y has a *connection weight value* $\boldsymbol{\omega}_{X,Y}$, often between 0 and 1, sometimes below 0 (negative effect) or above 1.
- **Combining multiple impacts on a state $\mathbf{c}_Y(..)$** For each state (a reference to) a *combination function* $\mathbf{c}_Y(..)$ is chosen to combine the causal impacts of other states on state Y.
- **Speed of change of a state $\boldsymbol{\eta}_Y$** For each state Y a *speed factor* $\boldsymbol{\eta}_Y$ is used to represent how fast a state is changing upon causal impact.

Combination functions can have different forms, as there are many different approaches possible to address the issue of combining multiple impacts. The applicability of a specific combination rule for this may depend much on the type of application addressed, and even on the type of states within an application. Therefore, the Network-Oriented Modelling approach based on temporal-causal networks incorporates for each state, as a kind of label or parameter, a way to specify how multiple causal impacts on this state are aggregated. For this aggregation a number of standard combination functions are made available as options and a number of desirable properties of such combination functions have been identified, some of which are the identity function and the advanced logistic sum function (Treur 2016), Chap. 2, Sections 2.6 and 2.7:

$$\begin{aligned}
&\mathbf{id}(V) = V\\
&\mathbf{alogistic}_{\sigma,\tau}(V_1, \ldots, V_k) = [(1/(1+\mathbf{e}^{-\sigma(V_1+..+V_k-\tau)}) - (1/(1+\mathbf{e}^{\sigma\tau}))](1+\mathbf{e}^{-\sigma\tau})\\
&\text{with } \sigma, \tau \geq 0
\end{aligned}$$

Here σ describes the *steepness* of the function when the sum $V_1 + \ldots + V_k$ is around the *threshold* value τ. A main scenario for the model for psychopathy introduced here is based on a situation where two persons that do not know each other are in a room, for example a waiting room at a train station. Person X walks out and unknowingly leaves his or her wallet behind. Person Y is left behind in the room with the wallet of person X and needs to decide to either take the wallet or not to take it, risking other people in the waiting room witnessing this. This decision is based on three main components that contribute to valuing of the decision options: gain, empathy and fear. The theories covered in Sect. 2 are the basis for the temporal-causal network model. Thereby the theories on the different systems that a psychopath's decision is based on, that is empathy and fear, are simplified to their essence in this model. The most relevant theories that were considered in designing this model are the following:

- The ability versus propensity of empathy in psychopaths.
- The dissociation between threat processing, automatic physiological fear processing and the conscious experience of fear in psychopaths.
- The amygdala is the key region in fear and emotion processing as well as empathy. This is both functionally and structurally deviating in psychopaths.
- The vmPFC and amygdala-vmPFC connection is essential in empathy. These structures are reduced in integrity and function in psychopaths.

In addition to these, the aspect of gain was addressed. Gain in this model comes purely from agent Y's prediction of how their situation will improve when they execute the action of grabbing the wallet for themselves. The states that are used are shown in Table 1. Except for ws_s, every state is representing a state of agent Y. The weights $\omega_{X,Y}$ represent with how much strength the first state X has impact on Y. Figure 1 shows a graphical conceptual representation of the network model for psychopathy. The simulation starts when the wallet is left, which reinforces itself because it does not change until the final action is executed. If the wallet is left behind in the room with person Y, the assumption is that person Y then observes the wallet. However, this connection can be adapted in the computational model. What follows is that observing the wallet strengthens the preparation of action a, which is to grab the wallet. The state of preparing to grab the wallet influences three representation states (gain, empathy and fear) as a way of valuing the action. In return these three states influence the preparation of action a. Each connection can be either a reinforcement or an inhibition. Finally, if the preparation state of action A reaches its threshold, it will trigger the execution of action a, which is to grab the wallet for themselves.

Additionally, fear is impacted by context, in a very risky situation fear will not be inhibited. Section 2 shows that empathy is possible in psychopaths, but it is most likely to be used in situations where empathy is estimated as useful by the psychopath. This is represented in the conceptual representation by the state "empathy regulation".

When empathy is useful, this reinforces the level of empathy in the psychopath. When empathy is not estimated as useful, empathy is inhibited. This is activated by person Y's sensory representation of gain. Meanwhile, the empathy state is monitored by the empathy regulation state.

The introduced model is connected to the background of neuroscience of psychopathy in the following ways. The regulation states, empathy regulation and fear regulation, and emotion states, empathy and fear, are each represented in different brain structures. The regulation states of the emotions fear and empathy take place in the vmPFC and the emotion states, empathy and fear, are represented in the amygdala. The connections between these states also represent the white matter connection between

Table 1. Overview of states and their explanations

State	Full name state	Explanation
ws_c	World State for context *c*	The context of the situation
ws_s	World State for stimulus *s*	Person X leaves wallet behind
ss_c	Sensor State for context *c*	Observing the context of the situation
ss_s	Sensor State stimulus *s*	Observing wallet
ps_a	Preparation State of action *a*	Preparation of grabbing wallet
srs_g	Sensory Representation State for *g*	Gain
srs_e	Sensory Representation State for *e*	Empathy, based in the amygdala
srs_f	Sensory Representation State for *f*	Fear, based in the amygdala
frs	Fear Regulation State	Fear regulation, based in vmPFC
ers	Empathy Regulation State	Empathy regulation, based in vmPFC
es_a	Execution State of action *a*	Execution of grabbing wallet
ws_w	World State stimulus *w*	The wallet being gone

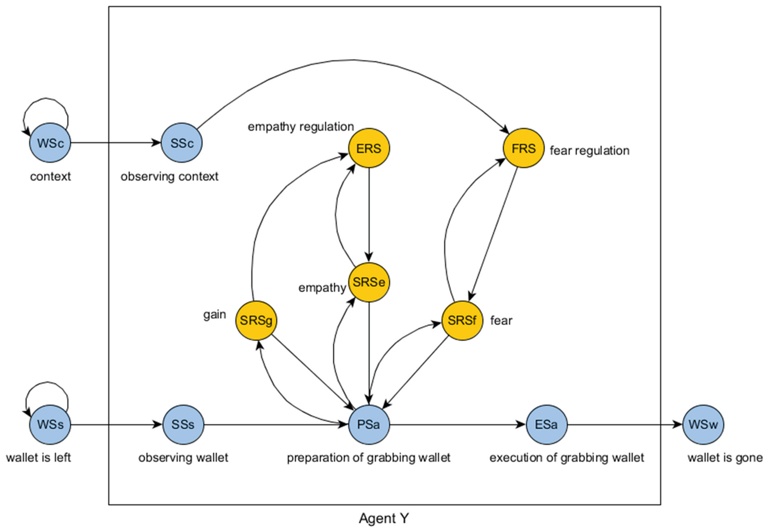

Fig. 1. Graphical conceptual representation of the network model

these brain structures. The regulation states, or control states model mechanisms that detect and adapt undesired levels of emotion by inhibiting connections. The more negative these connections, the stronger the suppression.

To run simulations, a numerical representation of above model of psychopathy is created. For simplicity, during the computational simulations only the in-agent portion of our model was used, where agent Y represents the person described in our scenarios. This is the person who needs to decide whether to take the wallet or not to take it. The simulations of these scenarios were ran using numerical software. In this software the conceptual representation of the model shown above is transformed into a numerical representation in an automated manner as follows; see Ch 2 in (Treur 2016):

- For each time t every state of the Y model has a real value in the interval [0, 1]
- For each time t every condition X connected to state Y has an effect on the state Y defined as $\mathbf{impact}_{X,Y}(t) = \boldsymbol{\omega}_{X,Y} Y(t)$
- The aggregated impact of state X_i on state Y at time t is determined by the combination function $\mathbf{c}_Y(..) : \mathbf{aggimpact}_Y(t) = \mathbf{c}_Y(\mathbf{impact}_{X_1,Y}(t), \ldots, \mathbf{impact}_{X_k,Y}(t)) = \mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y} X_1(t), \ldots, \boldsymbol{\omega}_{X_k,Y} X_k(t))$
- The effect of $\mathbf{aggimpact}_Y(t)$ on Y is exerted over time gradually, depending on the speed factor $\boldsymbol{\eta}_Y$: $Y(t + \Delta t) = Y(t) + \boldsymbol{\eta}_Y\, [\mathbf{aggimpact}_Y(t) - Y(t)]\, \Delta t$

$$\mathbf{d}Y(t)/\mathbf{d}t = \boldsymbol{\eta}_Y[\mathbf{aggimpact}_Y(t) - Y(t)]$$

- This generates a difference and differential equation for Y

$$Y(t+\Delta t) = Y(t) + \boldsymbol{\eta}_Y\left[\mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y} X_1(t), \ldots., \boldsymbol{\omega}_{X_k,Y} X_k(t)) - Y(t))\right]\Delta t$$
$$\mathbf{d}Y(t)/\mathbf{d}t = \boldsymbol{\eta}_Y\left[\mathbf{c}_Y\left(\boldsymbol{\omega}_{X_1,Y} X_1(t), \ldots., \boldsymbol{\omega}_{X_k,Y} X_k(t)\right) - Y(t)\right]$$

As an example, the obtained difference equation for state ps_a is

$$\begin{aligned}\mathrm{ps}_a(t+\Delta t) &= \mathrm{ps}_a(t)\\ &+ \boldsymbol{\eta}_{\mathrm{ps}_a}[\mathbf{c}_{\mathrm{ps}_a}(\boldsymbol{\omega}_{\mathrm{ss}_s,\mathrm{ps}_a}\mathrm{ss}_s(t), \boldsymbol{\omega}_{\mathrm{srs}_g,\mathrm{ps}_a}\mathrm{srs}_g(t), \boldsymbol{\omega}_{\mathrm{srs}_e,\mathrm{ps}_a}\mathrm{srs}_e(t),\\ &\boldsymbol{\omega}_{\mathrm{srs}_f,\mathrm{ps}_a}\mathrm{srs}_f(t)) - \mathrm{ps}_a(t)\,)]\Delta t\\ &\text{with } \mathbf{c}_{\mathrm{ps}_a}(..) = \mathbf{alogistic}_{\sigma,\tau}(\ldots..)\end{aligned}$$

Different software templates have been developed that automatically perform the above transformation and can be used to do simulation experiments, e.g., in Matlab, Python.

4 Simulation Experiments

A number of scenarios were created to use for running simulations and testing the model. Two of them will be discussed here.

- First, a basic scenario as starting point is the following. Person X leaves their wallet behind and person Y is a general person without psychopathy. This situation is called the ‘Regular Situation’.
- The second scenario is the situation in which a psychopath steals the wallet. This situation is called the ‘Psychopath’.

The expected results are the following for each scenario. In the basic scenario the goal is that person Y does not steal the wallet of person X. This person Y, as a regular person, would have healthy fear regulation. They would be apt to cooperate, which means that empathy is estimated as useful. The second scenario Psychopath addresses a case in which Y steals the wallet. This person Y would have strong fear regulation, which causes low fear. This is expressed by increased inhibiting connections from fear regulation to fear and increased support from gain to empathy regulation since gain plays an important part in the decision-making process. Empathy is not estimated as useful for this case, which is characterized by a strong inhibiting connection from empathy regulation to empathy.

The connections that are assumed to be impaired in individuals with psychopathy are: (ss_c, frs), (frs, srs_f), (srs_f, fr), (ers, srs_e), (srs_e, ers), (srs_g, ers) and (srs_g, ps_a). These are the connections that differ in weights and thresholds between the test scenarios. The in-agent portion of our domain model was used in simulations for simplification purposes. This is possible because all connections from outside to inside agent Y and from inside agent Y to outside are weighted 1. They are single impacts which means that values are passed through directly. Many simulations were ran to find values that would create a scenario very close to the domain model to test whether this model comes close to our interpretation of the neurological truth. These simulations also show a portion of what is possible to simulate with our model. In the graph for each scenario the colors are used with their representations as presented in Table 2. Furthermore, the weights that remain constant through all four tested scenarios are all 1 except for (srs_e, ps_a), (srs_f, ps_a), (frs, srs_f) and (ers, srs_e) which are −1. These are the connections that are not impaired in healthy individuals nor in individuals with psychopathy.

Table 2. Combination functions used

Color	Name	Description	Function
Turquoise	X1	Observing wallet	id(.)
Light Blue	X2	Observing Context (observing risk of scenario)	id(.)
Green	X3	Preparation of action (preparation of grabbing the wallet)	$\text{alogistic}_{\sigma,\tau}(..)$
Pink	X4	Gain	id(.)
Red	X5	Empathy	$\text{alogistic}_{\sigma,\tau}(..)$
Orange	X6	Fear	$\text{alogistic}_{\sigma,\tau}(..)$
Blue	X7	Fear Regulation	$\text{alogistic}_{\sigma,\tau}(..)$
Purple	X8	Empathy Regulation	$\text{alogistic}_{\sigma,\tau}(..)$
Lilac	X9	Execution of action	id(.)

The simulations all used speed factor 0.2. Initial values were 0 for all states except X1 and X2 (observing the wallet and observing the context). These states have initial values of 1 to initiate the simulation and to keep these states constant. In this section two figures are inserted as graphical representation of our scenarios. In these graphs the x-axis represents time and the y-axis represents activation levels ranging from 0 to 1.

Scenario 1 is the scenario where our agent Y is a non-criminal individual without mental illness. The graph in Fig. 2 represents the course of the simulation. In this graph, and in the other figure in this section, some similar characteristics can be observed. The states X1 and X2 are constant through all scenarios. For state X1, the observation of the wallet, and state X2, the observation of the context, this applies because these are constant states that are kept active. Note that some of the nine lines are not visible because they are covered by other lines. For example, gain is not visible because it is covered by the execution state.

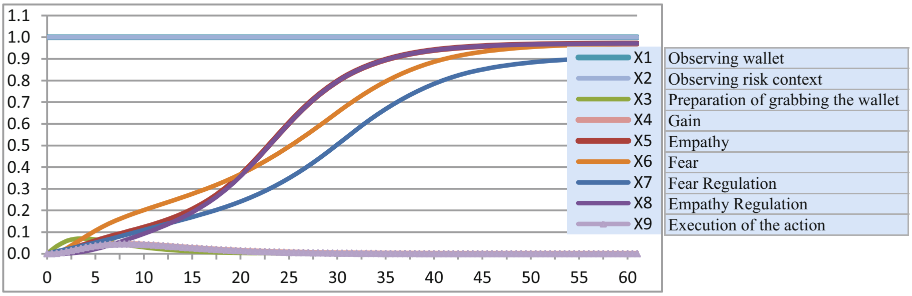

Fig. 2. A simulation of scenario 1: a regular person who does not take the wallet (time on horizontal axis, activation level on vertical axis)

Figure 2 shows state X3, that represents the preparation of action, and state X9, that represents the execution of the action. Both never rise higher than an activation of approximately 0.1. In this figure empathy (X1) works without suppression from empathy regulation (X8), which leads to a line that rises above activation of 0.9. Fear (X6) is also without suppression from fear regulation (X7), because the context of this situation is risky, considering that other people might witness the theft of the wallet. In this scenario the presence of fear and empathy outweigh gain in such a manner that the action of stealing the wallet is not executed. The steepness and threshold values that were used in this simulation are presented in Table 3 below. The connection weight for (ss_c, frs) was 0.3, and for (srs_g, ers) −0.1, the others were 1.

Table 3. Steepness and threshold values in scenario 1

State	X1	X2	X3	X4	X5	X6	X7	X8	X9
Steepness σ	5	5	15	5	5	5	5	5	200
Threshold τ	–	–	1.1	–	0.2	0.1	0.8	0.2	3.4

Scenario 2 is the main target scenario, when agent Y is an individual with psychopathy who steals the wallet due to fear and empathy being inhibited by their corresponding regulation states. Here the connection weights and thresholds are shown in Tables 4 and 5. They were determined based on the expected pattern.

Figure 3 shows, as the only scenario that does so, that preparation of action (X3) comes far of the ground and execution of action (X9) follows. Fear (X6) is inhibited by the fear regulation state (X7). Empathy (X5) is inhibited as well. The action of stealing the wallet is executed (X9 rises to an activation of 1) because the sensory representation of gain (X4) outweighs the inhibited fear and empathy.

Table 4. Connection weights in scenario 2

Connection	(ss_c, frs)	(srs_g, ps_a)	(srs_g, er)	(srs_e, er)	(ers, sr_e)	(srs_f, fr)	(frs, srs_f)
Weight	0.2	2	1	0.2	−1	0.8	−1

Table 5. Steepness and threshold values in scenario 2

State	X1	X2	X3	X4	X5	X6	X7	X8	X9
Steepness σ	5	5	15	5	5	5	5	5	200
Threshold τ	–	–	1.1	–	1	1.2	0.8	0.3	3.4

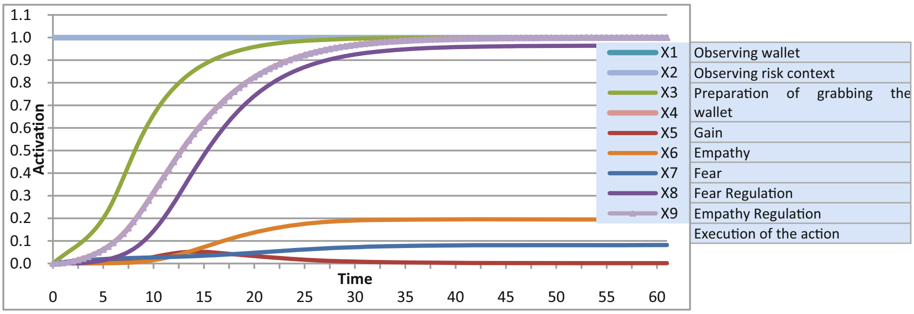

Fig. 3. A simulation of scenario 2: a psychopath who takes the wallet (time on horizontal axis, activation level on vertical axis)

5 Discussion

In this paper a temporal-causal network model was introduced to perform simulation experiments for internal processes and behaviour of a psychopath. It was found that psychopaths do not, by definition, have a deficit in cognitive empathy. It seems that at least for them empathy is not completely automatic, but that it is dependent on their attention or motivation. Similar findings exist on fear. Although it was found that there are differences in experience of fear between primary and secondary types of psychopaths, psychopaths seem to have a coping style for fear that protects them from these negative emotions, more than an average person. These findings indicate that there are some strong circuits active in psychopaths that regulate fear and empathy. This designed model was tested on four scenarios (two of which were presented in the paper) using numerical software, which have led to findings that approximate the expected outcomes of the test scenarios.

The parameters of the model such as thresholds and connection weights in this model can be altered to different types of simulation scenarios. The higher the threshold, the less easily the state of this threshold will be activated. The results from the scenarios that were tested come close to expected outcomes of the scenarios. To create realistic simulations, these weights were adapted to the values that are presented in our findings, but still a finer tuning of the model would be possible. Although the model was compared to qualitative empirical information through the scenarios, it has not been compared to real numerical empirical data yet.

In order to further refine this model, several options are possible. First, the model would benefit from further tuning, as mentioned above. Furthermore, literature about fear in psychopaths also touches upon problems in fear conditioning in psychopathic individuals. (Schultz et al. 2016; Hoppenbrouwers et al. 2016; Lopez et al. 2012). The amygdala is where associative learning of threat takes place, and it is a compromised structure in psychopathy. This fear conditioning problem could be an interesting addition to this model in the future; it would add learning capabilities to the model and provide an adaptive temporal-causal network model. Secondly, as empathy is represented by one state with one regulating state in our model, some refinement could be achieved here too, for example by adopting some elements from Treur (2016, Chap. 9).

Some longer term applications of the further developed model are the following. A virtual patient model that can be used for educational purposes. Such a virtual patient model enables students to see what the effect is of certain aspects of and changes in a patient without having to study a real patient. These virtual patient models could be personalized by changing the values of weights and thresholds. Another way such a virtual patient model could be useful is in the field of Criminology. Criminologists could use this model on offenders instead of on patients in order to study their behavior and their psyche.

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